Observations, &c.

U.S. Geological Survey. Mineral Resources of the United States. 1883 and 1884. 8vo. *Washington* 1885; Report of the Survey of the Territories. Vols. III (Book 1), VIII. 4to. *Washington* 1883, 1884. The Survey.

U.S. Naval Observatory. Report. 1888. 8vo. *Washington.* The Observatory.

U.S. Patent Office. Official Gazette. Vol. XLV. Nos. 10–13. Vol. XLVI. Nos. 1–5. 8vo. *Washington* 1888–89; Alphabetical List of Patentees, Quarter ending June 30, 1888. 8vo. *Washington.* The Office.

U.S. Signal Office. Report 1887. Part 2. 8vo. *Washington.* The Office.

Photograph of Commandant Defforges's Pendulum Apparatus as mounted in the Safe Room, Royal Observatory, Greenwich. The Astronomer Royal.

February 28, 1889.

Professor G. G. STOKES, D.C.L., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

I. "On the Spectra of Meteor-swarms (Group III)." By J. Norman Lockyer, F.R.S. Received February 14, 1889.

I. *Introductory.*

Up to the present time the prevailing idea has been that nebulæ, stars, and comets represent different orders of bodies in the cosmos, and all classifications have proceeded on the assumption not only that these bodies are variously constituted but that in the case of the "stars" all are becoming cooler. In a paper communicated to the Royal Society in 1865,* Dr. Huggins writes: "My observations, as far as they extend at present, seem to be in favour of the opinion that the nebulæ which give a gaseous spectrum are systems possessing a structure and a purpose in relation to the universe, altogether dis-

* 'Roy. Soc. Proc.,' vol. 14, p. 39.

tinct and of another order from the great group of cosmical bodies to which our sun and the fixed stars belong."

With regard to the most generally accepted classification of stars, that of Vogel, Dunér ("Étoiles à Spectres de la 3me Classe") writes, "Selon la théorie il faudra que tôt ou tard toutes les étoiles de la première classe deviennent de la seconde, et celles-ci de la troisième."

Vogel, and before him, others, working on the assumption that all the heavenly bodies were reducing their temperature, practically included all stars between the hottest and the coldest in one class (Class II*a* of Vogel).

In previous papers to the Royal Society I have adduced evidence to show that all cosmical bodies are or have been meteor-swarms, that at the present time some are increasing and some are reducing their temperature. Thus, in the Bakerian Lecture, 1888, I demonstrated that nebulæ and stars of Group II (Class III*a*) are still increasing in temperature by the condensation due to gravity, and that the red stars of Group VI (Class III*b*) are at a nearly equal mean temperature to stars of Group II, but are cooling bodies.

In these extreme cases the differentiation between the two groups was comparatively easy. In the case of those stars which are a little less hot than the hottest, whether they are getting hotter or cooler, the spectral difference cannot nearly be so well marked, as both classes will have line spectra; but it was essential to my hypothesis that these bodies should be resolvable into two groups, one increasing and one decreasing in temperature, with spectra proper to each.

The object of the present paper is to set forth the evidence which shows that this differentiation is possible, and to suggest the lines along which future researches on the subject might follow.

In this paper, which is only to be regarded as preliminary, I purpose to state the information already obtained with respect to Group III, and its relation to the two groups which bound it, in order that the validity of the distinction that I have drawn may be further tested. At present the observations are not sufficiently detailed to enable a classification into species to be made, as was done for Group II, so that we have to be contented with a general statement of the sequence of phenomena in passing from the early to the later stages of the group.

The observations lay no claim to great accuracy; only small dispersion has been employed, and only a reconnaissance has been attempted. The general method has been first to observe the differences between stars like Capella, which mostly resemble the sun, and those like α Cygni and α Tauri, which show marked variations. In this way the criteria which are hereafter enlarged upon were determined.

Particular attention was directed to the manner in which the flutings which form the special characteristic of Group II died out in

passing from Group II to Group III; and what other phenomena accompanied the transition, and what were the special phenomena which accompanied the gradual distension of the hydrogen lines in passing to Group IV. There has not been a sufficient number of fine nights since the work commenced to enable this to be done completely.

II. *General Statement of Conditions.*

A general statement of the conditions of the problem was given in the Bakerian Lecture (p. 26); and I here reproduce the greater part of what I then wrote on the subject.

"The passage from the second group to the third brings us to those bodies which are increasing their temperature, in which carbon radiation and fluting absorption have given place to line absorption. At present the data already accumulated by other observers have not been discussed in such a way as to enable us to state very definitely the exact retreat of the absorption—by which I mean the exact order in which the absorption lines fade out from the first members to the last in the group. We know generally that the earlier bodies will contain the line absorption of those substances of which we get a paramount fluting absorption in the prior group. We also know generally that the absorption of hydrogen will increase while the other diminishes.

"The next group—the Fourth—brings us to the stage of highest temperature, to stars like α Lyræ, and the division between this group and the prior one must be more or less arbitrary, and cannot at present be defined. One thing, however, is quite clear, that no celestial body without all the ultra-violet lines of hydrogen discovered by Dr. Huggins can claim to belong to it.

"We have now arrived at the culminating point of temperature, and next pass to the descending arm of the curve. The Fifth Group, therefore, will contain those bodies in which the hydrogen lines begin to decrease in intensity, and other absorptions to take place in consequence of reduction of temperature.

"It seems fair to assume that physical and chemical combinations will now have an opportunity of taking place, thereby changing the constituents of the atmosphere; that at first, with every decrease of temperature and increase in the absorption, lines may be expected, but it will be unlikely that the coolest bodies in this group will resemble the coolest bodies in Group III.

"Up to the present time observers have not recognised the importance of these considerations, and since only one line of temperature, and that a descending one, has been considered, no efforts have been made to establish the necessary criteria between Groups III and V."

It follows from the above that criteria are only possible from the

fact that on the ascending side of the curve the varying volatilities of the meteoritic constituents of the swarms brought out by successively higher temperatures are in question, whilst on the descending side of the curve we have to deal with successive chemical combinations, brought about by a fall of temperature in a gaseous mass.

III. *Relation between the Early Species of Group III and the Later Species of Group II.*

Since bodies of Group III are produced by the further condensation of the condensing swarms which I have included in Group II, there must be a close relation between the earlier species of Group III and the later species of Group II; that is, if there be anything like the continuity which my hypothesis demands. We know, for instance, that in the later species of Group II, there are flutings both dark and bright, and dark lines, amongst the latter being *b*, D, and E. As the lines are produced, so to speak, at the expense of the flutings, we should expect to find that lines of magnesium, sodium, manganese, and iron are the most prominent, especially in the earlier species of Group III. In α Orionis we have associated with the metallic flutings the lines *b* and D, and both are well developed, E is also present, but it is not nearly so strong as *b* or D. The F line of hydrogen is shown as a thin line in a photograph of the spectrum taken by Professor Pickering, although, as far as I know, it had not been previously recorded. With an increase in temperature, a condensing swarm like α Orionis would give a spectrum without flutings; the magnesium flutings would be replaced by *b*, and the iron fluting would be replaced by iron lines, of which E and the line at 579 would be the most prominent. F is absent in most of the stars of Group II, because the radiation of hydrogen from the interspaces is just sufficient to balance the absorption; but in bodies of Group III, the interspacial radiation will have almost disappeared, and absorption will be predominant. We shall thus have F appearing thin in the early stages of Group III, and gradually thickening until it becomes as thick as in α Lyræ.

In the earliest stages of Group III we should therefore expect to find F and E thin and *b* and D thick. As yet we have no evidence as to the first appearances of dark *b* and D in Group II, but future observations made with special reference to this point will at once indicate in what species they first make their appearance as absorption lines.

With the next increase of temperature F and E will thicken, but *b* and D will show no marked difference. With a further increase *b* and D will lose their supremacy, and will be only of about the same thickness as F and E, because most of the magnesium and sodium would have been driven out with the first rise in temperature. Afterwards all the lines, except those of hydrogen, will gradually thin out on

account of the increased temperature. Finally, the spectrum will be of the type represented by α Lyræ.

The question here arises, where are we to draw the line between Group II and Group III? If my definition of Group II as the "mixed fluting" group be accepted, we must obviously draw the line at the stage where carbon radiation disappears. The iron fluting at 615 remains for a considerable time after this happens, so that the earliest species of Group III will be marked by the absorption fluting of iron in addition to the characteristic line absorption. This being the case, observations show that Aldebaran is a good example of an early stage.

IV. *The Relations of the Later Species of Group III to Stars of Group IV.*

The spectrum characteristic of Group IV is that of excessive hydrogen absorption, with other lines exceedingly faint. In passing from Group III to Group IV, therefore, the hydrogen lines must thicken whilst the metallic lines thin. In a letter to M. Dumas in 1872 I suggested that possibly the simplification of the spectrum of a star might be associated with the highest temperature of the vapour, and that idea seems to have been accepted by other investigators since that time. It is now generally accepted that stars with thick hydrogen lines (Group IV) are the hottest stars.

The reason why we have hydrogen absorption in such great excess, is, I have little doubt, that most other substances have been dissociated by the intense heat resulting from the condensation of the meteoric swarm. We are, in fact, driven to this conclusion, because the hydrogen which was originally occluded by the meteorites must have been driven off long before this temperature was reached.

In passing from a star like α Tauri to one like α Lyræ, the metallic lines would thin and disappear in some order determined by their dissociability or some other quality. The later stars of Group III are therefore very closely related to stars of Group IV, and the division between the two must be more or less arbitrary. For simplicity's sake, I have taken Group IV as the point of maximum temperature.

V. *The Observations having reference to Specific Differences in Group III.*

The observations have been made at the Astronomical Laboratory at South Kensington by Mr. Fowler, assisted by Messrs. Baxandall and Coppen (with the 10-inch equatorial and star spectroscope by Hilger) in connexion with my own observations at Westgate (made with a 12-inch mirror, kindly lent to me by Mr. Common, and a small Maclean spectroscopic eyepiece). All measurements and comparisons suggested by my own observations were made by my assistants, as at

present I have no means of doing this myself. The stars selected for observation were a few of the brightest hitherto known as belonging to Class II*a* of Vogel's classification. A few stars more advanced than the II*a* stars and a few less advanced were also observed in order that the passage from one group to the other might be determined.

The main points to which attention was directed were (1) the relative intensities of F, *b*, E, D, both in the same star and from star to star; (2) the lines which appear to be special to one group or the other (III or V).

The importance of observing the thickness of F in the spectrum of a star, as compared with its thickness in other stars, is obvious, for it at once enables us to fix the position of the star on the temperature curve immediately we have determined whether its temperature is increasing or decreasing.

Details of the observations of the thirteen stars which appear to be on the ascending side of the temperature curve are given below. One of these is a Group IV star, and one is a swarm of the last species of Group II. The remainder belong to Group III.

The stars are arranged in order of temperature, beginning with the lowest, as far as the observations enable us to do this. In general, the observations have been limited to the region of the spectrum lying between F and the iron fluting in the red at wave-length 615.

The wave-lengths of the lines and flutings were determined by direct comparison with the electric spark, and with the lines and flutings seen when the various substances are volatilised in the Bunsen burner. On one or two occasions, comparisons were also made with the spectrum of the Moon.

α Ceti.—F is fairly well seen, but it is not nearly so thick as *b* or D, and not quite as thick as E. D is pretty thick and lies in the Mn (2) fluting (586). *b* is also thick. The trio of lines* in the green is present, the most refrangible member being the darkest. Lines are present at about 579 and 568·5, the former being the stronger. Lines at 499 and 552 rather thin. The absorption Fe (1) fluting at 615 and Mn (2) are both present, but far less intense than in Mira Ceti. The flutings Mn (1) 558 and Pb (1) 546, are also both feebly visible. The brightest fluting of carbon at 517 is just perceptible. This is therefore a very late star of Group II. It is, in fact, the most advanced Group II star of which observations have at present been made.

ι Aurigæ.—Spectrum greatly resembles that of Aldebaran. F is thin. D is very thick, and more prominent than *b*. The trio of lines in the green is well seen. 579, 568, and the lines near 546·5 and 558 are well seen. The lines at 499 and 552 are also present. The iron

* The trio referred to in the observations comprises the lines E (5268), 5327, 540.

fluting at 615 is present, and is a little stronger than in Aldebaran. This and the relative thickness of F lead to the conclusion that the star falls between α Ceti and Aldebaran. Carbon 517 has disappeared.

α *Tauri.*—F, E, and 499 are all about the same intensity, but none of them are so strong as *b* or D. The trio is present, E being a little thicker than the second and third members. All three are seen to be double when a high power eyepiece is employed. 579 is nearly as thick as E and is stronger than 568. Groups of lines near 546 and 558 are fairly strong. 552 is also well seen. The Fe (1) fluting in the red (615) appears rather weak, and a pretty strong line runs through it near the most refrangible edge. There is also a line between *b* and 499, another between E and 5327, and many others. The Mn (2) (586) fluting is possibly visible at times.

χ *Ophiuchi.*—F is slightly stronger than in α Tauri, but is a little thinner than E. Not so thick as in α Cygni or α Serpentis. D is the strongest line in the spectrum and *b* comes next. 579 and 568 are both about the same intensity as E; so is 540, whilst the remaining member of the trio is rather weaker. The lines near 546 and 558 are fairly strong, as is also 499. The iron band in the red is absent.

β *Ophiuchi.*—F and E are about equally thick in the spectrum of this star. F is thicker than in Arcturus, but is not so thick as in α Cygni. The trio is complete, all the three lines being very well seen. *b* is the strongest line in the spectrum and D is the next. 568 is present, but weaker than 579. The lines near 546 and 558 are also certainly present. The line at 499 is about as thick as E. 552 is present.

ϵ *Pegasi.*—F is about as strong as in α Aquarii; D and *b* are about equal and as strong as F. 579 is stronger than 568 but is not quite so strong as D. E and 540 are not nearly as strong as 579; the other member of the trio (5327) is very distinct. 499 and the lines near 546 and 568 are all fairly strong. 552 is also present.

α *Aquarii.*—F and *b* seem about equal in intensity in the spectrum of this star. D is not quite so strong as *b*, but is a little stronger than E; the other two lines of the trio are rather faint. 579 is about as strong, or perhaps stronger, than E. 568 is much weaker than 579. 499 is a fairly strong line. The lines near 546 and 558 are well visible.

γ *Aquilæ.*—F is not nearly so strong as in α Aquilæ, and is a little thinner than in α Cygni. *b* and D are well defined, and about equal in intensity, whilst E is a little weaker; the remaining members of the trio are fainter than E. 579 and 568 are present, the former being about as strong as E, but the latter is barely visible. 499 and the faint lines near 546 and 558 are present; also an important line less refrangible than D, which was found by comparison with the electric spark to be near 598. Another fainter line was seen near 612.

α Cygni.—All lines except those of hydrogen are rather faint. F is the thickest line, G could not be seen very well, but C was well visible. D is fairly strong in comparison with *b* or E. E seems a little fainter than *b*, but stronger than the other members of the trio. 579 and 568 are seen, the former being much the stronger; it is almost as strong as D. The line near 499 is not very strong, and there appears to be a line on each side of it. The faint lines near 546 and 558 are also visible.

γ Cygni.—The lines are much easier to see and much more numerous than in α Cygni, although the whole spectrum is very much fainter. F is thicker than in α Cygni, and G is also visible. D and *b* are about equal in intensity, E is about the same as D, but much stronger than the other members of the trio. 579 is nearly as strong as E, but much stronger than 568. 499 is faint but certainly present. The lines near 546 and 558 are also present.

δ Cygni.—All the lines except those of hydrogen are faint. F and G are thicker than in γ Cygni, and therefore thicker than *b* or E, whilst E is thicker than the other members of the trio. 579 is a little stronger than 568. 499 and the lines near 546 and 558 are about equal, but very faint.

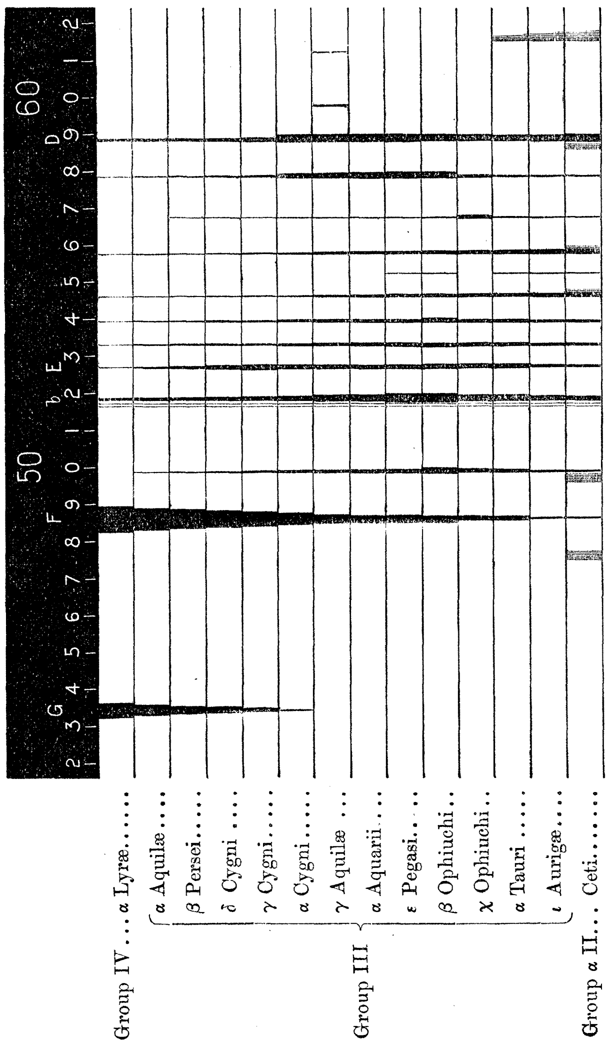
β Persei.—All lines faint with the exception of those of hydrogen. F and G both thick. *b*, D, and E are about equal in intensity. The remaining two members of the trio are also as thick as E. 579 is present, but 568 could not be seen. There is also a line near G, about 450; it is seen in the Henry Draper Memorial photograph of the spectrum of this star as a double, but it could not be resolved with the power used.

α Aquilæ.—All lines very faint except those of hydrogen. F and G very thick. *b*, D, and E very faint but about equal in intensity. 579 is not quite so strong as D. 499 is fairly well seen, as are also the two lines near 546 and 558.

α Lyræ.—All the lines except those of hydrogen are exceedingly faint. F is very strong but G is not quite so thick. *b* and D are fine lines, and about equal in intensity. The trio is undoubtedly present as also the lines near 546, 558, and 579.

The results of the observations which have been referred to are embodied in fig. 1. The star at the lowest temperature is on the lowest horizon, and the one at the highest temperature is on the top horizon. The thicknesses of the lines have been greatly exaggerated in the diagram, in order to render the variations more obvious.

Fig. 1.



Map showing the spectra of some of the stars of Group III, and of α Ceti and α Lyræ, arranged in order of temperature.

The wave-lengths and origins of the lines and flutings recorded in the observations are shown in the following table :—

Wave-length.	Origin.	Wave-length.	Origin.
434 (G)	Hydrogen.	552	Magnesium.
486 (F)	,,	558 (fluting)	Manganese (1)
499	?	,, (line)	?
5166 } (b)		568	Sodium.
5172 } (b)	Magnesium.	579	Iron.
5183 } (b)	Manganese.	586 (fluting)	Manganese (2).
5268 (E)	Iron.	589 (D)	Sodium.
5327	,,	598	?
5400	Manganese.	612	?
546 (fluting)	Lead (1)	615 (fluting)	Iron.
,, (line)	?		

VI. *Criteria between Groups III and V as deduced from the Observations.*

The general conclusion to be drawn from the observations is that there are several lines in the spectra of stars on the ascending side of the temperature curve, which do not occur in stars with a spectrum resembling that of the Sun, which must lie on the descending side of the curve, as we know it to be cooling.

Some lines, such as F, *b*, D, and E, are common to both sides of the curve, though the relative intensities are slightly different.

The principal criterion in the visible part of the spectrum is the double line about wave-length 540, which, with the two iron lines E (5268) and 5327, forms the trio referred to in the observations. Each member of the trio is seen to be double when a high power is used. These three equidistant lines, which are of nearly equal intensities, are well seen in Aldebaran and several other stars, but are not seen as such in either Arcturus or Capella.

In Arcturus and Capella, as in the Sun, there is a double line (5403, 5404·9) which makes an almost equidistant trio when combined with E and 5327. Direct comparison with Group III stars, however, shows that the lines are not coincident. On one or two occasions the spectra of some stars of Group III were compared with the spectrum of the Moon; in the absence of the Moon, comparison was made with Arcturus or Capella. A comparison of the Group III line with the Mn line at 540 referred to in previous papers shows a perfect coincidence with the dispersion employed; and since both are double we are driven to the conclusion that the 540 line in stars of Group III is due to manganese. Again, the double in Group V is considerably weaker than E, whereas that in Group III

is very nearly as strong as E. The appearance presented to the eye by the real trio in stars of Group III is accordingly very different from that presented by the three lines in stars of Group V.

Besides the least refrangible member of the trio there are other lines which are special to Group III. One of these lies between F and *b*, at wave-length 499, as nearly as can be determined with small dispersion. In some of the stars this line is very strong. It is only seen as a very faint line in Capella, Arcturus, or the Sun, and is consequently an important criterion. The nearest line of anything like equal importance in Group V stars is the iron line at 495·7.

Two lines, at 579 and 568 respectively, also appear to be special to Group III. No lines of similar intensities are seen in either Capella, Arcturus, or the Sun in those positions, although fainter lines are seen.

In Rowland's photographic map of the solar spectrum there is a line at 5659 which is much stronger than the one nearest to 568, and this is not seen at all in Group III stars. Only a very faint line is indicated in the same map at 5791, there being a stronger line at 5763 which is not seen in Group III stars. The two lines at 568 and 579 are, therefore, special to Group III. The line at 579 was compared directly with the low temperature iron line at 579, and the coincidence established with the dispersion employed; this may, therefore, be taken as due to iron. It may also be suggested that the line at 568 is the double green line of sodium, which appears bright in some of the bodies of Group I. Other lines referred to in the observations are near 546 and 558, but it is not easy to distinguish these from lines seen in stars of Group V. There are several strong lines seen in the solar spectrum in the neighbourhood of 546, and there are also strong lines at 5573 and 5587. In order to determine whether these lines will serve as criteria or not, further inquiry with greater dispersion will be necessary.

The magnesium line 5527 appears to be common to both Groups III and V, just as *b* is common to both.

There seems to be no doubt, therefore, that criteria between Groups III and V have been determined by the observations, and we are now in a position to assign the stars of Vogel's Class II*a* to one group or the other according as the lines which have been shown to be special to Group III are present or absent.

One of the chief objects I have had in view in writing this paper is to enable others to take up this important piece of work as soon as possible when once the idea of increasing and decreasing temperatures is generally accepted.

VII. *Tests.*

We have an important test of the accuracy of the preceding observations in tracing the continuity of the lines in passing from the earlier to the later species of the group. In the map which accompanies this paper, the stars have been arranged in order of temperatures by reference to the thickness of F, it being universally agreed that those stars in which the hydrogen lines are thickest are the hottest. With the stars in this order we ought to find that if a line be visible in any two of the stars, it is also visible in any other star of the group in which F is of an intermediate thickness. On first arranging the stars in this way, it was found that there were here and there breaks in the continuity of the lines, but further observations, made with special reference to the breaks, showed that the discontinuity was due to the incompleteness of the first sets of observations. The only break now shown on the map is the apparent absence of Mg 5527 in χ Ophiuchi, and this was not discovered before the star had got too far to the west to be re-observed.

We have another test in tracing the variations in the intensities of the various lines in passing through the series. Assuming that a sufficient number of stars have been taken, there ought to be no abrupt change in the thickness of a line in passing from star to star. The temperature at which a line is at its maximum thickness will depend on the volatility of the substance which produces it, so that all the lines need not necessarily have their greatest thicknesses in the same star. The continuity as regards the intensities of the lines is quite as perfect as could be expected from a preliminary survey. Thus D gradually thins from α Ceti to α Lyræ; *b* thickens from α Ceti to ϵ Pegasi, and then thins gradually to α Lyræ. This difference in the behaviour of *b* and D is obviously due to the fact that all the sodium would be distilled out of the meteorites before all the magnesium was driven out. E (5268), 5327, 540, and 499 gradually thicken to β Ophiuchi and then thin out. The line at 579 is almost equally thick in β Ophiuchi, ϵ Pegasi, α Aquarii, and γ Aquilæ. The line at 568 has a decided maximum in χ Ophiuchi. The lines near 546 and 558 have their greatest thickness in the earliest stage of the group, gradually thinning out towards the last. The remnant of the iron fluting (615) is seen to gradually disappear between α Ceti and α Tauri; no trace of this fluting was seen with the dispersion employed in any of the stars of a higher temperature than α Tauri. As the fluting disappears it is replaced by iron lines of gradually increasing intensities. The hydrogen line at G was not seen in any of the stars below α Cygni, but it does not follow that it was absent, because the lower stars being generally fainter, the attention of the observers was not directed so far into the blue.

It will be seen, then, that the continuity is practically perfect, both as regards the intensities of the lines and the presence in each star of the lines necessary for perfect continuity.

VIII. *Sequence of Spectra in Group III.*

The general sequence of spectra in passing from the earlier to the later species of Group III is as follows, as far as the observations have at present gone:—

(1.) The hydrogen lines are thin. D is thicker than *b*. The iron fluting is faint. 499, E, 5327, 540, 568, and 579 are thin. 546 and 558 are fairly thick.

(2.) The hydrogen lines are thicker. F, D, and *b* are equally thick. E, 5327, 540, 579, and 499 are much thicker, being nearly as strong as F. The iron fluting has gone.

(3.) The hydrogen lines are very much thicker than the other lines. D and *b* are equally thick. E is nearly as strong as *b*, while the other lines are fainter.

(4.) The hydrogen lines are very broad, while all the remaining lines are exceedingly faint.

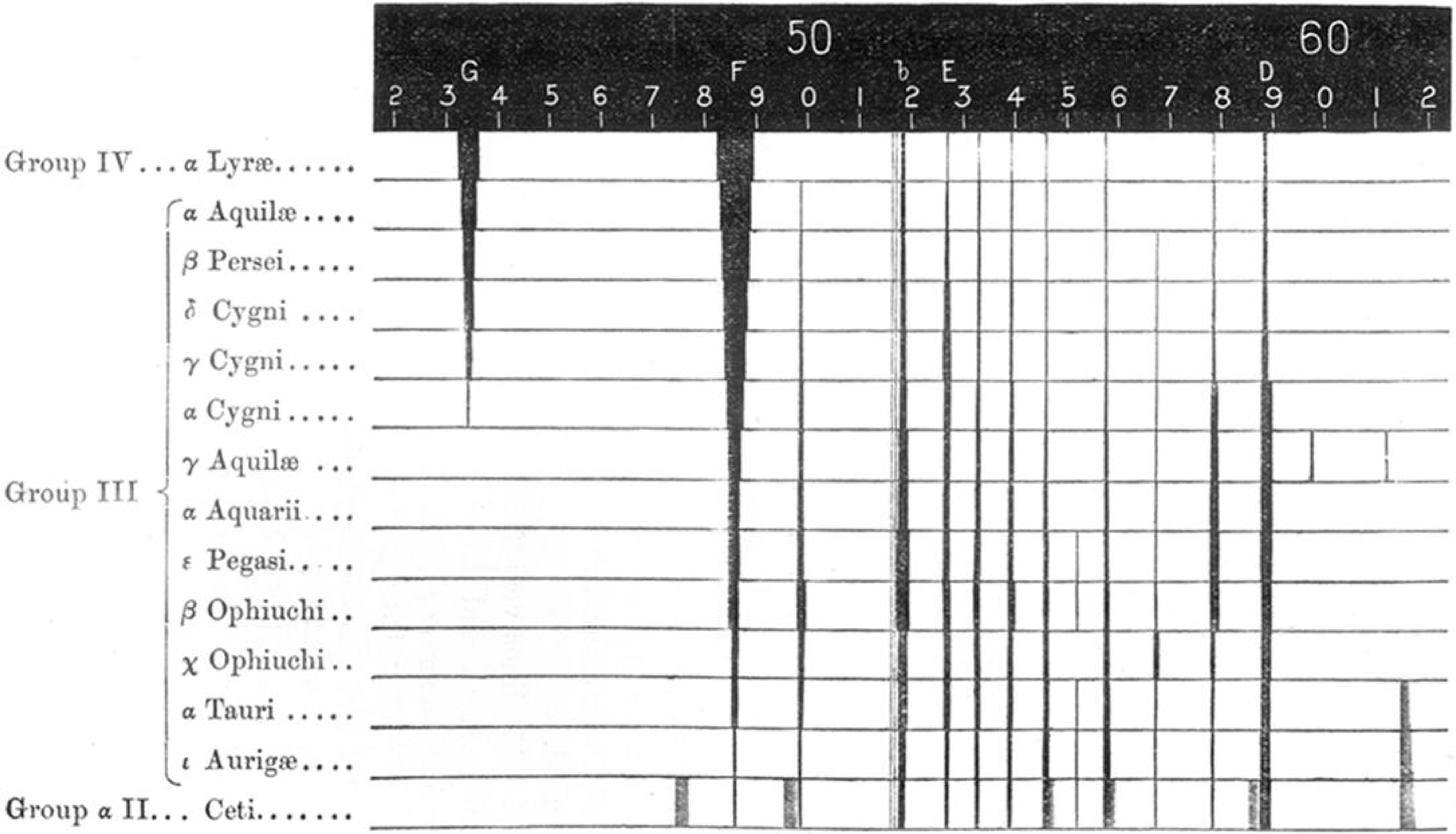
Subsequent work will no doubt enable us to further divide these sub-groups into finer species.

II. "On the Magnetic Action of Displacement-currents in a Dielectric." By SILVANUS P. THOMPSON, D.Sc., B.A. Communicated by Professor G. CAREY FOSTER, F.R.S. Received February 19, 1889.

(Abstract.)

According to Maxwell's well-known views of electrostatic action, the variations of electric displacement which occur during the charge or discharge of a dielectric are to be regarded as equivalent to electric currents. No direct experimental proof of this point has hitherto been forthcoming. The author having calculated out on the assumption of the equivalence between displacement-currents and conduction-currents, what the effect would be of the charge or discharge of a condenser upon a delicately astatised needle placed near the edge of the condenser, concludes that the effects would be too delicate to be measurable. He therefore resorted to a different method based upon the principle that, if a closed curve be drawn around the flux of electrostatic displacement, the line-integral of the magnetising force, reckoned once round this closed curve, will at any instant be a measure of the rate of change in the electric displacement through the curve. Two forms of apparatus for realising this in an experi-

Fig. 1.



Map showing the spectra of some of the stars of Group III, and of α Ceti and α Lyræ, arranged in order of temperature.